Recycling Hybrid Maize Varieties: Is It Backward Practice or Innovative Response to Adverse Conditions in Kenya?

W. JAPHETHER
H. DE GROOTE
M. LAWRENCE
D. KENGO
L. MOHAMMED

**Poster paper prepared for presentation at the
International Association of Agricultural Economists Conference,
Gold Coast, Australia, August 12-18, 2006**

Copyright 2006 by W. JAPHETHER, H. DE GROOTE, M. LAWRENCE, D. KENGO and L. MOHAMMED. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

Recycling Hybrid Maize Varieties: Is it backward practice or innovative response to adverse conditions in Kenya?

Summary

Hybrid varieties have significantly contributed to increased maize productivity in Kenya and other Sub Saharan African SA countries. A number of factors like high costs, low price of maize grain and non-availability of preferred varieties limit access of farmers to improved maize varieties. Farmers resort to the alternative option of recycling the hybrid maize seeds. Seeds are carefully selected based on cob and grain size during or before harvest after which they are preserved. Hybrid maize varieties (HMV) developers and disseminators observe that there is a progressive yield decrease of recycling HMV and discourage farmers from recycling. The question is 'Is it uneconomical to recycle HMV or an innovation that farmers can practice?' This study was designed to evaluate the yield losses and benefits of hybrid maize recycling in Kenya. Through key informants, farmers who grew both certified seed and recycled maize were identified and randomly selected. For on farm trials (OFTs), sixty two (62) farmers who recycled hybrid maize varieties and 30 who grew certified seeds were randomly selected while for the on station trial (OST), the trial was laid out in a completely randomized block design replicated four time with plots measuring 100M square. For the OFT, two plots of 100 square meters were superimposed on farmers' fields both on recycled and fresh seed. Input and output levels in the plots were identified and valued. The results showed that the yield decreases at an increasing rate. Yield losses for Double crosses were low compared to the top crosses. The yield levels of recycled top cross reduced by 16%, 17% and 32 while that for double crosses decreased by 20%, 37% and 46% for the first, second

and third recycling generations respectively. However, positive net benefits are attained in recycling HMV. This implies that it is beneficial to recycle HMV up-to the third generation level. However, at regional and national level, food security objective is compromised. This demands that incentives to discourage farmers from recycling may be sought through development of OPVs which can be recycled if national objective of food security has to be enhanced. From the logit results the major significantly influencing factors in recycling HMVs are amount of credit, fertilizer, wealth and extension contact which if addressed may discourage farmers from recycling.

Recycling Hybrid Maize Varieties: Backward practice or innovative response to adverse conditions in Kenya?

1.0. INTRODUCTION

Despite technology developers and disseminators emphasizing that hybrid maize varieties developed from inbred lines should not to be recycled (Allan 1971; Hallauer 1997; Neal 1995, Shumba 1990, Rice et al 1997), a significant portion of farmers in Kenya and other sub-Saharan African countries still practice (Heisey et al 1997; Morris et al 1999). Currently, it is estimated that about 30% of maize area in sub-Saharan Africa is planted under hybrid maize. The rest of the area is under recycled maize varieties, which include high hybrid maize varieties (HMV), local landraces (LL) and Open pollinated varieties (OPV) (Ligeyo, 1997, Onyango 1997 and Onyango *et al* 1998). The recycling of HMV is termed as a backward practice among technology developers and disseminators. In Kenya, depending on the price of maize grain among other factors, it is estimated that between 10-40% of farmers still recycle maize varieties and area under HMV has decreased compared to the 1992 Maize Data base survey (Hassan, 1998). According to Ochieng' and Tanga (1995) recycling leads to a yield loss of about 20% to 50%. The recycling is attributed to both socio-economic and biological factors (Morris and Rizopouluos 1999; Akulumuka *et al* 1997; Zambezi al. 1997)). These factors include; lack of cash to purchase increasing cost of certified seed, preference to specific HMVs not accessible on the market and limited knowledge on the biology of breeding (Mose *et al* 2002). For example the cost of maize seed has risen from KSh 4.40 per kilogram in 1980 to about KSh 120.00 in 2005. Therefore with high cost of maize production one of cost reducing strategy is to use recycled seed. Farmers prefer recycling specific hybrid maize variety because of sweetness and stable yields even with sub-optimal input use (low yielding environments) (Ombakho *et al* 1998). According to Morris *et al* (1999) and Pixley and Banseger 2002) recycling of maize varieties leads to loss of hybrid vigour due to contamination, genetic drift, mutation, natural selection and segregation (Heisey et al 1997 and Morris et al 1999).

Development of maize varieties in Kenya dates back to 1950s with the first variety released in 1961 and in 1964 H611 was released (Gerhart 1975). HMVs are developed from crossing pollen from male plant with female, which forms the seed with an isolation distance of not less than 200 meters to avoid adulteration. This is aimed at increasing the yields among other preferred traits embedded in the varieties. The number of varieties has increased drastically from one in 1964 to about fourty in 2005. The increase could be attributed to market liberalization of the seed industry in 1994 (GoK 2002; GoK 1994 and Nyoro 1999). During this period yields were improved from 3 tons per ha to about 7 tons per ha. Varieties from bred outside Kenya came in after liberalizing maize seed sector in 1994. The objectives of the study are to: identify the criteria used to select recycled maize varieties for production; document the processing of the recycled maize varieties for growing; and assessing the profitability of growing the most recycled maize varieties. Therefore based on this understanding is it economically viable to recycle HMVs?

2.0 MATERIALS AND METHODS

Conceptual Frame work

Hybrid maize was scientifically bred to reap maximum yields from F1 generations. The benefits and genetic make up and therefore vigour of the hybrids vary from variety to variety. However, with recycling the hybrid vigour is lost. Farmers who recycle forgo some benefits while on the other hand saving on some costs. Thus, farmers weigh the benefits and costs in making decisions on whether to recycle HMV or not. The decision by farmers to recycle is assumed to be rational and is driven by a number of factors which include farm, farmer and other socio-economic in nature.

Data type and sources

Data for the study was generated from farm surveys (2003) and on-farm trials (2002-2003). The survey was carried out in 2003/2004 and covered the six major maize agro-ecological zones namely; Low Tropics (LT); Moist Transitional (MT); Moist mid altitude (MM), dry transitional (DT), Dry mid transitional (DT), High tropics (HT) (Hassan, 1998). Farmers were randomly selected from a list of farm households developed at village level. Using a structured questionnaire, a total of 1800 households were randomly selected using simple random sampling technique. Data for the on-farm trials were collected from 60 sites distributed in three districts with a back-up trial at the research center. Plot sizes were 10meters by 10 meters ($100m^2$). Agronomic and economic data were collected from the participating farmers. The data included: type and generation of variety, land preparation, time of planting and weeding, harvesting and post harvest activities including yield levels. Qualitative data on seed selection and processing by farmers were also collected. In order to quantify benefits and costs, all inputs (seed, fertilizer, recycled HMVs, labour) and outputs (grains) were identified and quantified and prices pegged on them through a semi-structured questionnaire. Farm gate prices including transaction costs (transportation costs) were added to the purchase price. The quantification of benefits and costs was done through monitoring of all production activities, inputs and outputs that went into the two plots. This was a farmer managed trial but the design was done by research-extension team. Thus the farmer participated in all the activities of the trial including harvesting.

Data analysis

Partial budgeting and logit regression model is used to evaluate the qualitative and quantitative implications of economic use of recyc ling HMVs. The models were specified as shown in equations 1-3. For partial budgeting the benefits of using recycled HMVs were compared to the costs, using data of on-farm trials. The Gross benefits per hectare of product I, is defined as the yield Y_i, times price P.

$$Gross - Benefits = Y_i P_y \quad \text{Equation 1}$$

The Net benefits (*NB*) are defined as Gross benefits (Y_i times maize price) minus Total variable costs (TVC) which is a summation of all inputs X_i times their respective prices P_x (equation 2) (CIMMYT, 1988).

$$Net - Benefits = Y_i P_y - X_i P_x \quad \text{Equation 2}$$

The logit model was used to evaluate factors influencing incidence of growing of recycled maize varieties. Logit model is a logistic distribution bound between 0 and 1. The model was specified (Theil., 1979) and , Maddala, 1983) as shown in equation 3.

$$\log\left[\frac{\Pr ob(event)}{\Pr ob(no-event)}\right] = b_0 + b_1X_1 + ... + b_kX_k \qquad \text{Equation 3}$$

Where ß$_{is}$ are estimated coefficients and X, are independent variables such as farmer and farm characteristics. The variable hypothesis and descriptions in the model are shown in Table 1.

Table 1. Variables used in the Logit model for regression analyses of recycling HMV

Variable name	Nature of variable s	Unit	Variable description	Expecte d sign
Dependent				
RecyDumy	Binary		Adopters of grows recycled HMVs. 1=grows HMV; 0 otherwise	
Independent				
Acre	Continuous	Ha.	Acreage under maize is an indicator of income source which may influence farmers to adopt pesticide use	-ve
YldMze	Continuous	Kg	Yield per hectares is an incentive for farmers to adopt pesticide use.	+ve
Herb	Continuous	Kg/ha	Amount of Herbicide though a competitor for cash was a proxy to the importance farmers attach on maize and hypothesized to negatively influence farmers to recycle	-ve
TotFert	Continuous	Kg/ha	Amount of fertilizer use. Farmers use less of fertilizer on recycled maize hypothesized to negatively influence farmers recycling	-ve
LabHa	Continuous	Hours per ha	Total of labour in maize production and it is hypothesized to positively flounce farmers to adopt pesticide use	+ve
QtyMzeSel	Continuous	Kg/hh	Quantity of maize sold was hypothesized to negatively influence farmers recycling	-ve
Age	Continuous	Years	Age of household head can be a proxy to experience and was hypothesized to positively influence farmers to farmers who recycle .	+ve
Gender	Binary		Gender of household head. This was dichotomous variable (1=male; 0=female), which influences access and control of capital. Hypothesized to negatively influence recycling	-ve
Educ	Continuous	Years	Education of household head in years. Was hypothesized to influence the farmer. More years in school meant less likely to recycle HMV	+ve
%TimeOnF	Continuous	%	Time on-farm of household head was an indicator of sourcing for cash to complement farm expenditures. Hypothesized to positively influence recycling	+ve
ExtCont	Binary		Farmer training was hypothesized to negatively influence farmers to recycling	-ve
Wealth	Continuous		Was hypothesized to negatively influence farmers recycling	+ve

InsectHa	Continuous	Kg/ha	Quantity of insecticide per ha. On recycled maize and was hypothesized negatively influence recycling	
Credit	Continuous	KSh	Amount of credit hypothesized to positively influence farmers recycling	+ve

3.0 RESULTS AND DISCUSSION

General characteristics

The general farm characteristics are shown in Table 2. The average age of farm household heads that recycle was 49.3 years while those who grow only fresh seed was 49.4 years. On the other hand the average number of years in school for those who recycles was significantly lower than those who grow fresh seed. In addition that percentage time of those farmers who recycle was significantly higher than those grow fresh. This may be attributed to engagement in off-farm income generating activities of farmers who grow fresh seed. However from the data set there was no significant difference in farm sizes of farmers who recycle and those growing fresh seed. The percentage of farmers recycling ranged from 10% to 35% in all the six maize zones in Kenya. The variability could be attributed to differences in resource base of farmers and yield potential.

Table. 2. General characteristics of Households heads who grow recycle and fresh HMV

Variable	Recycles		Fresh	
	Mean	Sd	Mean	sd
Age	49.3	4.4	49.4	14.8
Education years	6.2	4.4	7.4	4.0

% time on-farm	74.1	36.9	60.5	38.0
Distance to markets	2.2	5.5	2.5	15.7
Farm size	4.5	3.2	4.4	3.9

Selection and Processing of recycled maize Seed

Farmers exert selection pressure on recycled HMVs by carefully selecting and processing seed. This contributes to reduction in yield between fresh seed and recycled HMV materials. The major sources of recycled seed were own farm crop (50%), neighbours (30%) and from the open market (20%). The seed from neighbours is either given free by neighbours or bought as a commercial crop from the market.

Farmers who select seed from own crop, did this either during harvesting of the whole field or before. For those who selected seed when harvesting the whole field, they picked good-looking big cobs and grains. Big stocky stems were a good indicator of the above-mentioned characteristics. After harvesting, the cobs were shelled and preserved using chemicals in bags a waiting planting season. Some farmers picked the seed when the maize crop had reached physiologically maturity and still in the field. They selected cobs and stored them above fireplace. This maize was then shelled just before planting. In all cases farmers shelled grains from the central part of the cob and avoided the grains from the tip and base of the crop.

Input utilization in Recycled hybrid maize in Kenya

From the survey both recycled and fresh HMV production scenarios received external inputs but at varying rates (Table 3). In most of AEZs, the seed rate was higher for the recycling than fresh material. This could be attributed to may be due to poor germination anticipated by farmers and lower cost of the seed of recycled seed. In all cases fertilizer application was lower than the optimal rates of 120 kg per ha. For basal and 150 kg for top-dress fertilizers. The lower rates could be attributed to escalating cost of fertilizers against the relatively lower output prices. On the contrast all farmers hire in labour for both recycled and fresh HMV production.

Table 3. Input utilization in recycled and fresh HMV production in Kenya.

Zones	Variable	Inputs and yield levelels of farmers growing				Zone	Inputs and yield levelels of farmers growing			
		Recycled seed		Fresh seed			Recycled seed		Fresh seed	
		Mean	SE	Mean	SE		Mean	SE	Mean	SE
MT n=418	Seed rate/ha.	30.28	1.06	15.65	1.06	DT n=100	28.8	3.85	24.72	5.41
	Total fertilizer rate/ha	82.14	12.31	191.6	25.3		81.11	31.61	147.7	42.6
	Hired labour hours/ha	51.63	17.7	134.18	23.6		641.65	148.9	1975	546
	Total labour in maize prod/ha	409.44	58.27	434.63	45.1		2608	388.1	6014	1292
	Maximum maize yield kg/ha	5058	810.9	7204.9	700		3314.3	740.6	13110	4983
	Minimum maize yield kg/ha	2798.3	60.46	464.73	119		462.04	83.2	3342	900
LT n=300	Seed rate/ha.	9.69	0.5	7.81	0.59	DM n=100	28.46	1.52	22.05	1.83
	Total fertilizer rate/ha	11.27	4.47	40.44	12.5		2.18	0.79	14.49	3.67
	Hired labour hours/ha	162.5	23.75	213.23	46.1		202.47	35.81	305.5	140
	Total labour in maize prod/ha	1075.9	69.77	1241.7	134		1425	105.8	2161	445
	Maximum maize yield kg/ha	2198.4	172.6	2079.9	239		1771.9	102.9	2480	392
	Minimum maize yield kg/ha	511.17	44.9	571.07	70.7		368.3	32.25	394.2	61.8
MM n=250	Seed rate/ha.	21.45	0.7	16.98	0.85	HT n=400	27.17	2.67	26.62	0.86
	Total fertilizer rate/ha	17.04	2.93	51.51	6.56		167.25	29.96	228.3	12.6
	Hired labour hours/ha	226.18	35.67	155.06	40.3		224.14	70.82	322.9	31.7
	Total labour in maize prod/ha	1483.9	71.29	1114.6	85.3		808.72	170.2	743.7	67.5
	Maximum maize yield kg/ha	1826.3	105.4	2153	227		8474	2193	6802	679
	Minimum maize yield kg/ha	700.52	49.74	1044.6	129		4650.6	1955	3109	303

How much yield do farmers loose when recycling HMV?

As shown in Table 4, of all the hybrid recycled, yield losses for double crosses is lowest compared to the Top crosses. The yield levels of recycled Top cross (H614) reduced by 16%, 17% and 32 while that for double crosses (H625, H626, H627, H628) decreased by 20%, 37% and 46% for the first, second and third recycling generations respectively. The yield losses are attributed to a number of factors which include loss of hybrid vigour and sub-optimal input use of inputs (e.g. fertilizers).

Table 4. Yield losses due to recycling HMVs in Kenya.

Variable	Generation level			
	Certified	1st. Recycling	2nd. Recycling	3rd. Recycling
Hybrid double cross	2199	1781	1430	1188
% Yield loss for double cross		20	37	46
Hybrid top cross	1788	1504	1489	1211
% Yield loss for top cross		16	17	32

How profitable is recycling HMVs?

The yield losses have economic implications to the producer, buyer, consumer and the whole economy at large in terms of food provision and lost revenue. Farmers, who recycle hybrid maize seed, therefore save on cost of purchasing seed. This gives positive net benefits for the recycled. Though there are positive net benefits from recycling HMVs (Table 5), there is loss of revenue at an increasing rate. This could be why most farmers do not recycle beyond the third generation levels. Thus it is not economical to recycle seed.

Tables 5. A partial budget analysis of recycled verses fresh high yielding hybrid maize.

(Exchange rate 1 US$=KSh. 75.00)

Variety name/kind	Profitability indicator by generation level			
Double crosses	Certified	1st. Recycling	2nd. Recycling	3rd. Recycling
Total Revenue (KSh)/ha	60328.75	47706.75	37354.25	31536.75
Total cost (KSh)/ha	29774	24803.5	23117.75	23117.5
Net benefits (KSh)/ha	30554.75	22903.25	14236.5	8419.25
Top crosses				
Total Revenue(KSh)/ha	58095	48879	48391	39370.5
Total cost (KSh)/ha	29774	24803.5	23117.75	23117.5
Net benefits (KSh)/ha	28321.25	24075.5	25273.25	16253

Source: On-farm trials 2002-2004

Determinants of recycling hybrid maize varieties

According to the logit results indicated in Table 6, the amount of fertilizers negatively influences the household head to recycle HMVs. The higher the amount of fertilizer to be applied the less the likelihood of recycling. Higher fertilizer application requires more cash and most farmers who recycle are cash constrained and cannot afford or willing to invest in fertilizers. The amount of labour hours for the family and hired labour positively and significantly influence the farmer to recycle. Thus, the higher the family labours the higher the likelihood of recycling. Wealth status of individuals negatively and significantly influences the recycling. The higher the wealth status the less likely the farmers will recycle the seed. Wealthy farmers have the ability to purchase fresh seed. In addition amount of credit positively and significantly influences the farmers to recycle. The higher the credit received the less likely the farmer will recycle. Credit could be in terms of cash or kind (eg fertilizers) so farmers who get more credit are likely not to recycle the seed. Contact with extension service negatively influences the likelihood of recycling. Access to extension services provides greater access to information concerning hybrid vigour, so they are likely not to recycle. Education level of HHH negatively influences farmers not to recycle. However, the coefficient is not significant. Also Pesticides and herbicides are high input options for the farmer so if the farmer cannot afford to buy seed it is expected that he is unlikely to apply the inputs. However the coefficients were not significant.

Table 6. Logit model factors influencing adoption of Recycled maize in Kenya

Variable	Coefficients	SE.	t-value
Quantity of seed per ha.	0.0003	0.0018	0.1700
Quantity of herbicide per ha.	0.0049	0.0042	1.1600
Quantity of insecticide per ha.	-0.0008	0.0009	-0.9600
Quantity of fertilizer per ha.	-0.0018***	0.0006	-3.0100
Quantity of labour per ha.	0.0002**	0.0001	2.8200
Amount of maize sold in kg per household	-0.0000	0.0000	-0.1000
Extension contact	-0.2344*	0.1341	1.7500
Wealth per household (number of cattle)	-0.3931***	0.1247	-3.1500
Age of household head in years	0.0019	0.0044	0.4300
Education of household head (years)	-0.0005	0.0139	-0.0400
Gender of household head	0.2307	0.1988	1.1600
Amount of credit per Household per year (KSh)	-0.4337***	0.1375	-3.1500

Constant	0.3112	0.3591	0.8700

*Log of likelihood function = 817.9451, Pseudo R-squared=0.576; chi-square=<0.001; Number of observation=1287.

4.0 CONCLUSION AND POLICY RECOMMENDATIONS

From the results, there is loss in grain yields when recycling maize HMVs. Despite positive net benefits, the loss in yields increases at an increasing rate. This may demand that for incentives to farmers not to recycle HMVs , open-pollinated varieties (OPV) that have recycling option be developed . These incentives can be in terms of favorable input–output pricing strategies. The development of OPV that could have similar characteristics to the most preferred and recycled HMVs may attract farmers to grow and recycle it without significantly loosing the grain yield. It is possible that farmers are aware of reduction in yields when they recycle the seed but the ability to invest in fresh seed is curtailed by socio-economic constraints like the pricing along with other high input production technological components.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Sygenta foundation for sustainable agriculture for providing funds through CIMMYT for this study. The director KARI and Centre director KARI Kitale are acknowledged for providing full support for the work. The technical support from CIMMYT, government ministries of agriculture and the provincial administration

significantly contributing to the work. Farmers and other stakeholders who actively and directly or indirectly contributed to this work are recognized.

REFERENCES

Akulumuka V., Mduruma Z., Kaswende J., and Nkonya E., 1997., Factors influencing maize recycling and their implications to hybrids. In CIMMYT maize propgram. Maize Productivity Gains Through Research and Technology Dissemination. Proceedings of the Fifth Eastern and Southern Africa Regional Maize Conference, Held in Arusha, Tanzania 3-7 June 1996 pp 146-148.

Allan A. Y., 1971., The influence of agronomic factors on maize yields in Eastern Kenya with special reference to the time of planting. Ph. D., Thesis Makerere University

CIMMYT, 1988, From Agronomic data to farmer recommendation. Mexico D F.

Gerthart J., 1975., The diffusion of Hybrid maize in Western Kenya-Abridged by CIMMYT. Centro Internacional de Mejoramiento de Maiz Trigo. Mexico City

GoK. 1994, *Sessional Paper No. 2 of 1994 on National Food Policy.* Government printer, Nairobi/. Kenya.

GoK. 2002, *National Development Plan 2002-2008.* Government Printers, Nairobi.

Hallauer, A.R. 1997. Heterosis: What have we learned, what have we done, where are we headed? In: CIMMYT, 1997. *Book of abstracts. The genetics and exploitation of heterosis in crops; An international symposium.* Mexico, D.F., Mexico.

Heisey, P., M.L. Morris, D. Byerlee, and M.A. Lopez-Pereira. 1997. Economics of hybrid maize adoption. In: M.L. Morris (ed). 1997a. *Maize seed industries in developing countrie*s. Boulder, Colorado: Lynne Rienner Publishers.

Hassan, R. M. (1998 ed.). Maize technology development and transfer: A GIS application for research planning in Kenya (pp. 121) CAB International, CIMMYT and KARI.

IRMA. 2001, Socio-economic Draft Report presented in Annual general meeting. Held in November, 2001. in Hilton Hotel.

Ligeyo, D. O., 1997., The Kenya Maize Breeding Programme achievements and Strategies for future Research. In Rees D. J., Nkonge C. and Wandera, J. L. (Eds) 1997. A review of agricultural practices and constraints in the north of Rift Valley Province, Kenya.

Maddala, G. S., 1983. Limited-dependent and qualitative variables in econometrics. Cambridge. University press. New York.

Morris M. L., Risopoulos J., and Beck D. 1999. *Genetic Change in Farmer-Recycled Maize Seed: A Review of the Evidence.* CIMMYT Economics Working Paper No. 99-07. Mexico, D.F.: CIMMYT.

Mose L.O, Wanyama J. M., Kigen W. M., Gogo M and Mutoko M. 2002, Maize production and marketing in Trans Nzoia district in a Liberalized market. In KARI Socio-economic conference held in KARI Hqs Conference hall in April 2002. In press.

Neal, N.P. 1935. The decrease in yielding capacity in advanced generations of hybrid corn. *Journal of the American Society of Agronomy* 27: 666-670.

Nyoro,, J. K. Kiiru, M. W., and Jyne, T. S.; 1999., Evolution of Kenya's Marketing Systems in the Post-Liberalization era.

Ombakho G. A., Ligeyo D. O. and Laboso A. K., 1998., Smallholder farmers in Kenya prefer H614 maize cultivar: A cultivar with similar characteristics and adaptability responses identified. *In* In CIMMYT and EARO 1999. *Maize Production Technology for the Future: Challenges and Opportunities. Proceedings of the Sixth Eastern and Southern Africa Regional Maize Conference, Held in Addis Ababa, Ethiopia 21-25 September 1998*. CIMMYT (International Maize and Wheat Improvement Centre) and EARO (Ethiopian Agricultural Research Organization). Pp 89-91.

Onyango R. M. A., 1997., A review of Practices and constraints for Maize production in the North Rift part of Kenya. In Rees D. J., Nkonge C. and Wandera, J. L. (Eds) 1997. A review of agricultural practices and constraints in the north of Rift Valley Province, Kenya.

Onyango R. M. A., Mose L. O., Achieng' J. O., and Ng'eny J. M. 1998., Changing selected maize agronomic practices to suit farmer circumstances in the North Rift. In Bezureh T., Oedraogo, S., Zongo J. and Ouedraogo M. 1998. Towards Sustainable Farming system in Sub Saharan Africa. Publication of African Association of Farming Systems Research-Extension Training Ouagadougou, Burkina Faso.

Ochieng J. A. W. and Tanga H. M.,1995, Maize yields losses due to farmers' use of own seed saved from previous maize crop. East African agro-forestry journal (1995) 60 92) pp 209-211.

Pixley K., and Banziger M., 2002., Open-pollinated maize varieties: a backward step or valuable option for farmers? Paper presented at the 7th. Eastern Africa Regional Maize Conference, Nairobi, Kenya, 11-15 February 2002.

Ranson J. K., Palmer A. F. E., Zambezi B. T., Mduruma Z O., Wadington S. R., Pixley K. V., and Jewell D. C., CIMMYT MAIZE PROPGRAM. *Maize Productivity Gains Through Research and Technology Dissemination.* Proceedings of the Fifth Eastern and Southern Africa Regional Maize Conference, Held in Arusha, Tanzania 3-7 June 1996

Rice, E., M. Smale, and J.L. Blanco. 1997. Farmers' use of improved seed selection practices in Mexican maize: Evidence and issues from the Sierra de Santa Marta. CIMMYT Economics Program Working Paper 97-03, Mexico, D.F.: CIMMYT.

Shumba, E.M. 1990. Yield comparison of first and second generation hybrid and open pollinated maize cultivars under similar growth.

Theil H., (1979)., Principles of Econometrics. Centre for Mathematical Studies and Economics. The University of Chicago. John Wiley & Sons New York.

Zambezi B. T., Nyondo F. K., Nkhono G., Mbingwani G. F., and Chakhuta T. F., 1997., Evaluation of recycled hybrids at three levels of nitrogen in Malawi. In CIMMYT MAIZE PROPGRAM. Maize Productivity Gains Through Research and Technology Dissemination. Proceedings of the Fifth Eastern and Southern Africa Regional Maize Conference, Held in Arusha, Tanzania 3-7 June 1996 pp 153-160.